SEMIANNUAL REPORT

August '94-February '95

High Tc Superconducting Bolometric and Nonbolometric Infrared (IR) Detectors

NASA GRANT n° NAG 5-2348

Principal Investigator:

Dr. Samuel Lakeou
Professor
University of the District of Columbia
Department of Engineering & Technology

Research Associate:

Dr. M. Rajeswari
University of the District of Columbia
Department of Engineering & Technology

Research Assistant:

Ms. Anuja Goyal
Graduating Senior
University of the District of Columbia
Department of Engineering & Technology

CONTENTS

STATUS REPORT

I. Workplan for the period August 94-August 95

The workplan for the period August 1994 through August 1995 includes the following:

1. Expansion of the Applied Superconductivity Laboratory to include stand-alone optical response and noise measurement setups;

2. Pursue studies of the low frequency excess electrical noise in YBCO films; and

3. To enhance the academic support component of the project through increased student and faculty participation.

II. Expansion of the Applied Superconductivity Laboratory at UDC

a) Optical response measurements

As reported in the annual report last year, the pilot Applied Superconductivity Laboratory at UDC is currently well equipped for DC electrical transport measurements in the temperature range 10K to 300K. In the current year we plan to expand this laboratory to include a facility for low frequency optical response measurements. Toward this end the following additional equipments have been acquired :

- He-Ne laser source and the necessary optical bench and accessories;
- A light chopper with variable frequency;
- A variable temperature cryostat with optical windows*;
- A temperature controller* to replace the temperature controller currently on loan from the Center for Superconductivity Research at the University of Maryland; and
- A 30 liter Dewar* for supply and storage of liquid nitrogen.

*Items expected to be delivered very shortly.

The optical response setup will also be utilized to study photo conductivity and superconductivity in YBCO and other oxide superconductor thin films.

One of the main efforts in this direction will be the study and evaluation of the optical response in YBCO films doped with copper substituents such as Co, Fe; Ze; Ga and Ni. Some of these dopants shift the superconducting transition temperature to lower values retaining sharp transitions necessary for good optical responsivity. This makes it possible

to fabricate high responsivity detectors for a desired temperature of operation by controlling the dopant concentration in the YBCO thin films. We will, with the collaboration of the CSR fabricate high quality dopant incorporated YBCO thin films and evaluate their performance as radiation detectors at various temperatures.
The results of our joint work with the CSR on the dopant incorporation in epitaxial YBCO thin films as well as on their electrical properties are expected to be presented at the Spring '95 American Physical Society Meeting in San Jose, CA (see attachment for abstracts).

b) Electrical noise measurements

Currently, in collaboration with the CSR at U. of MD, we have set up a facility for electrical noise measurements at the center. The results of our ongoing experiments have been presented at a poster session (see section III for detail) at the Fall '94 meeting of the Material Research Society in Boston, MA. This year, we plan to expand the Pilot Applied Superconductivity Laboratory at UDC to include a stand-alone noise measurement setup. To this end, the following equipments have been acquired:

- A lock-in amplifier*;
- A low noise voltage preamplifier;
- A transformer;
- A spectrum analyzer**; and
- Other miscellaneous accessories.

* Acquired since last year (see attached equipment inventory)
** Made available by the Department of Engineering and Technology at UDC

This noise measurement facility will be carried out in the variable temperature optical response cryostat with necessary modifications. Coupled with the transport and optical response measurements and our access to the thin film deposition and characterization facilities at the CSR, this would enable the Applied Superconductivty Laboratory at UDC to carry out state-of-the-art research related to materials and device issues for the development of HTSC based radiation detectors.
One of the major problems we will focus on in our electrical noise studies is the correlation between the micro structure of the thin films and their electrical noise characteristics. This issue is very pertinent for the development of high quality radiation detectors due to the following reason. For optimal device performance the detectors need to be fabricated on substrates such as silicon, sapphire, diamond etc. and the films on such substrates do not have the best micro structure as a result of poor lattice and/or thermal expansion mismatches of these substrates zith YBCO. We will investigate the effects of the resultant micro structural defects (such as grain boundaries) on the electrical noise

characteristics.
Further, in conjunction with optical response measurements, we will evaluate the electrical noise characteristics of dopant incorporated YBCO thin films. Since the dopantsareknown to significantly alter the electrical transport and vortex dynamics in YBCO, study of the electrical noise characteristics in the doped films would be of interest both in evaluating potential radiation detectors based on these materials as well as in understanding the basic physics of how the dopants alter the electrical transport and superconductivity.

III. Studies of the Low Frequency Excess Electrical Noise in YBCO films

We have conducted experiments to study the dependence of the excess electrical noise in YBCO films on the micro structure of the films. The micro structure is expected to play an important role since the conductance fluctuations which give rise to the excess noise are expected to have a dominant contribution from the defect fluctuations which are coupled to the concentration and mobility of charge carriers.

In our experiments the YBCO films with different micro structures are obtained by depositing the films on different substrates. The films were grown by pulsed laser deposition. In this report we present the results of our noise measurements in films on three different substrates :

(i) YBCO / (100) $LaAlO_3$: The lattice mismatch of YBCO films with (100) $LaAlO_3$ is < 1 % as a result of which the film micro structure is very nearly single crystalline. The thermal expansion coefficient of the substrate and the film are also well matched

(ii) YBCO / Poly crystalline Yttria Stabilized Zirconia (Poly YSZ) : The substrate is poly crystalline and hence there is no in-plane alignment of the YBCO film with the substrate resulting in the formation of low angle grain boundaries. Since the film is poly crystalline any strain resulting from thermal expansion mismatch would be relieved via the formation of defects.

(iii) YBCO / CeO_2 buffered R-plane Sapphire : In this case, the lattice mismatch between YBCO and the CeO_2 buffer layer is better than 1% as in the case of YBCO / $LaAlo_3$.

Hence structurally the films are nearly single crystalline with no grain boundaries. However, unlike in the case of YBCO / $LaAlO_3$ there is considerable mismatch between the thermal expansion coefficients of YBCO and Sapphire which is expected to result in stresses in the film during the film growth process .

a) Structural Analysis by X-ray Diffraction

We have done detailed structural analysis in these films using the 4-circle x-ray diffractometer facility at Univ. of Maryland in order to correlate the micro structural information with the results of our electrical noise measurements. The F scan analysis reveals good in-plane alignment in the case of YBCO/ $LaAlO_3$ as well as YBCO/ Sapphire while no in-plane alignment is observed in the case of YBCO / Poly YSZ as expected. Rocking angle analysis reveals a good degree of c-axis texturing in all the three cases. The rocking angle FWHM ism ~0.3^{o} in the case of YBCO / $LaAlO_3$, 0.7^{o} in the case of YBCO / Sapphire and ~ 0.9^{o} in the case of YBCO /Poly YSZ.

b) Electrical Noise Measurements & Analysis

The films were patterned into micro bridges for the noise measurements. Contact pads of Ag were thermally evaporated. The contacts were annealed at $500^{o}C$ in oxygen to obtain low contact resistances. We measured the excess electrical noise in these films in the standard 4-probe geometry. The samples were biased with a DC current from a battery operated source. A large ballast resistance was connected in series with the sample to minimize current fluctuations. The sample voltage was capacitively filtered to eliminate the DC component and transformer coupled to a low noise amplifier. The amplifier output was given to a dynamic signal analyzer to obtain the noise spectral density by Fourier transform . Our initial studies reported here focus on the excess electrical noise in the normal state of these films . In Fig.1 and Fig.2 we show the frequency dependence of the noise power spectral density (S_V) and the bias current dependence of the noise voltage spectral density ($S_V^{1/2}$) respectively. The linear bias current dependence and the $1/f^a$ (a =1.1) frequency dependence observed are characteristic of conductance fluctuations . In order to compare the magnitude and the temperature dependence of the noise in the three films we have analyzed the measured noise spectral density in the framework of HoogeÕs [1] empirical formula for conductance fluctuations. HoogeÕs relation is given by

$$S_V = g\ V_{DC}^2 / N_c f^a \text{..} (1)$$

where N_c is the total concentration of charge carriers in the sample volume and g is a constant representing the strength of the noise sources. From equation (1), we obtain the normalized noise power spectral density as

$$S_V * f^a * v / V_{DC}^2 = g / n_c \quad \text{...} (2)$$

where v is the sample volume and n_c is the volume density of charge carriers. The normalized noise spectral density thus represents an intrinsic material property given by g / n_c. In Fig. (3) we show this quantity as a function of temperature for the films on the three different substrates. The most striking aspect is the enhancement in the normalized noise power in the films on poly YSZ by nearly 6 orders of magnitude as compared to the single crystalline films on $LaAlo_3$. This clearly indicates that the grain boundaries when present are a dominant source of excess noise. The noise levels in the films on Sapphire are intermediate between that of the films on $LaAlO_3$ and the films on poly YSZ. While the films on Sapphire are single crystalline, the enhancement of the noise level may be associated with the strain present in the films due to the mismatch of the thermal expansion coefficients. In addition to the three films we have also studied the normal state excess noise in YBCO film on $LaAlO_3$ which has been de-oxygenated there by decreasing T_c below 77 K . This film shows enhanced noise levels close to that of YBCO / Poly YSZ. This result indicates that oxygen vacancy fluctuations could be a dominant source of noise has been indicated by some other recent studies[2,3] as well. The results described above were presented at the 94 MRS Fall meeting at Boston. A more detailed paper is currently under preparation.We are at present continuing our investigations to extend these studies to the behavior of the electrical noise in the transition range.

c) Work on Doped YBCO films ($YBa_2Cu_{3-x}M_xO_{7-y}$) :

In collaboration with CSR at Univ. of Maryland we are currently studying the properties of YBCO films in which the chain / plane copper sites are partially substituted by dopants such Fe, Co, Ga, Al etc. These dopants have several interesting effects on the properties of the films such as changes in the inter layer coupling between the superconducting CuO_2 planes. We have optimized the preparation of these films by PLD and are currently studying some of the properties such as normal state and superconducting electrical transport , electrical noise , optical response etc. Some of these dopants suppress T_c while retaining sharp transitions and may thus be relevant to the fabrication of bolometers operating at temperatures other than 90 K. The operating point may be tuned by varying the dopant concentration. We plan to present some of the results of our work at the APS 95 March meeting at San Jose, California. The related abstracts are enclosed.

References

1. P. Dutta and M. Horn, Phys. Rev. B 53 , 497 (1981)
2. Yizi Xu et al , Proc. Appl. Supercond. Conf. Boston, 1994
3. Li Liu et al , Phys. Rev. B 49 , 3679 (1994- I)

IV. Academic support

As reported previously, the dissemination among the students and faculty of the UDC community of the theory and application of High Tc superconductivity was primarily achieved through the offering of a course on Applied Superconductivity as part of the technical elective offerings at the Department of Engineering and Technology at UDC. However, this year additional means of involving students in basic research in the characterization of HTSC materials were sought. One such means is the sponsoring of laboratory fellows who under the College of Professional Studies Laboratory Fellowship Program will be allowed to participate in semester long assignments at the Pilot Applied Superconductivity Laboratory. At present, the academic support component of the project includes the following:

- Offering of a course on Applied Superconductivity
  (Textbooks: Introduction to Superconductivity, A. C. Rose-Innes
  Foundations of Applied Superconductivity, Orlando & Delin);

- Sponsoring of Laboratory Fellows at no cost to the project
  (see attachment for lab fellow presentation in Fall '94);

- Invited speakers on selected topics on High Tc superconductivity & its applications (3 such seminars planned for the year). One such seminar was organized on Monday January 31, 1995 on the topic of "Bolometric Properties and Optical Response of HTSC";

- Participation of senior students of the program of Electrical Engineering in specific projects to be conducted in the pilot laboratory. In fact, the current research assistant, Ms. A. Goyal is working at the laboratory on a project that will fulfill her Senior Project requirement in the program of Electrical Engineering. She is working on setting up a computer controlled data aquisition system for measuring the optical response of YBCO samples.

This academic support component of our project will be further strengthened after the acquisition of additional equipments in the laboratory (optical response and noise measurement equipments)

ATTACHMENTS

INVENTORY OF EQUIPMENT (INCLUDING SOFTWARE)
(AS OF 6/30/94)

Name of Equipment	**Serial Number**	**Price**
Cryostat	E-1211	On Loan from CSR
APD Cryogenics	--	On Loan from CSR
Lake Shore Cryogenics 820 Cryogenic Thermometer	09228	On Loan from CSR
SR530 Lock-In-Amplifier Stanford Research Systems	07663	3,990.00
KEITHLEY 224 Programmable Current Source	0558147	3,443.00
KEITHLEY 195A Digital Multimeter	0562707	1,755.00
SCIENTIFIC INSTRUMENTS INC. Microprocessor-Based Temp. controller. **SERIES 5500**	--	On Loan from CSR
ALCATEL Motor Pump	FM052093	928.00
Surge Protector		9.95
ALCATEL Pressure Gauge	270B44	903.00
Mobile Rack	--	859.00
Helium Cylinder & Regulator	--	399.00
COMPUTEC 486 Computer & Accessories	129338628	4,600.00
Electronic Temperature Controlled Soldering Station	XY9-60DK	150.32
NATIONAL INSTRUMENTS Data Acquisition Board BNC-2080	000891	337.00
LabVIEW FOR WINDOWS 3.1	12448A70	1,296.00
NATIONAL INSTRUMENTS GPIB Board AT-GPIB	776207-51	517.00
NATIONAL INSTRUMENTS AT. MIO-16X Adapter for Data Acquisition & Cable	776578-01	1,795.50
EG&G 197 Light Chopper	9-0606	1,390.00
He Ne Laser U - 1335(10 mw)	1032325	1,616.00
Electronics Tool Kit & Miscellaneous	--	321.45

Fig. 1 Frequency Dependence of Noise Power Spectral Density Sv

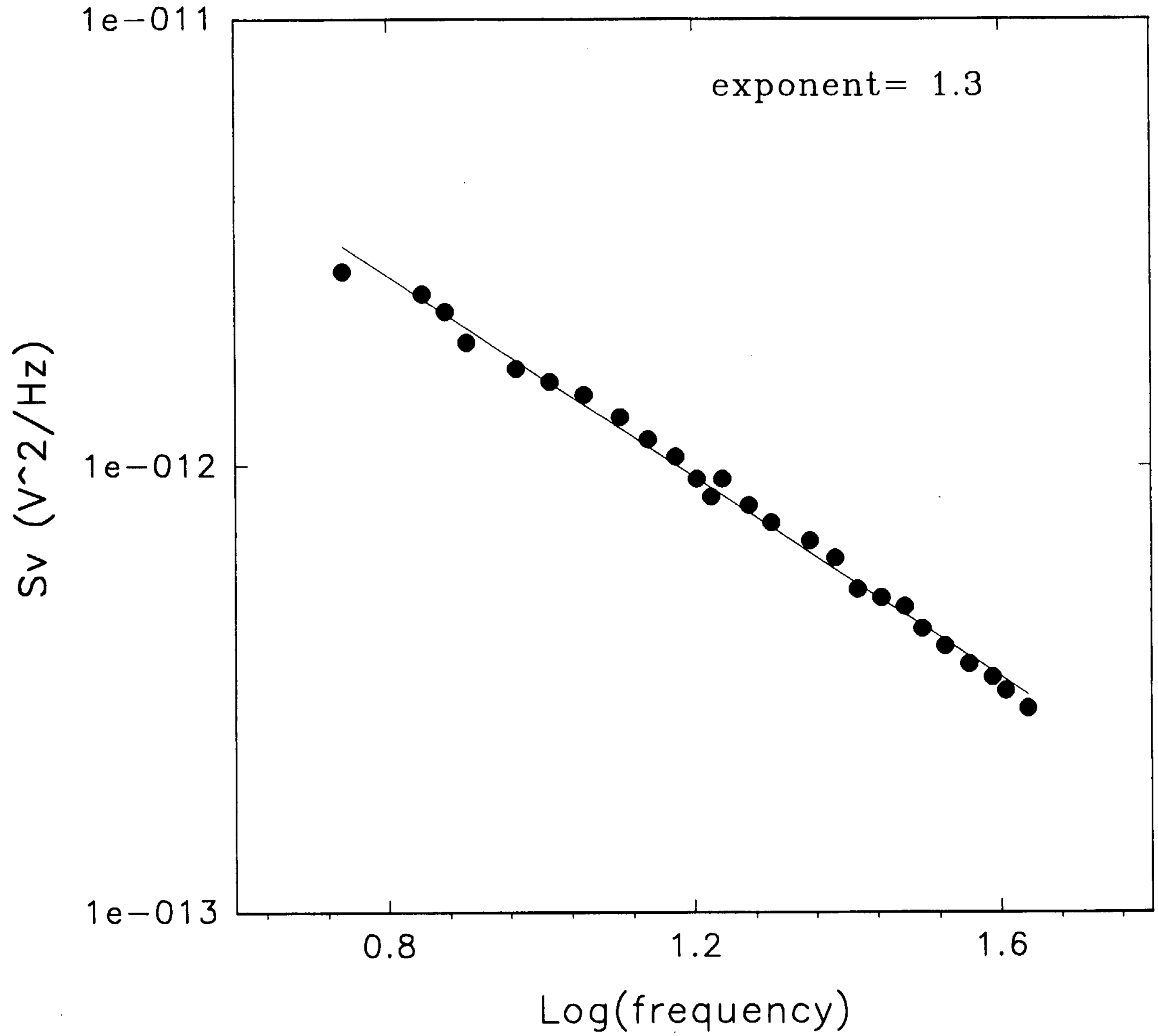


Fig. 2 Bias Current Dependence of the Noise Voltage Spectral Density $S_v^{1/2}$

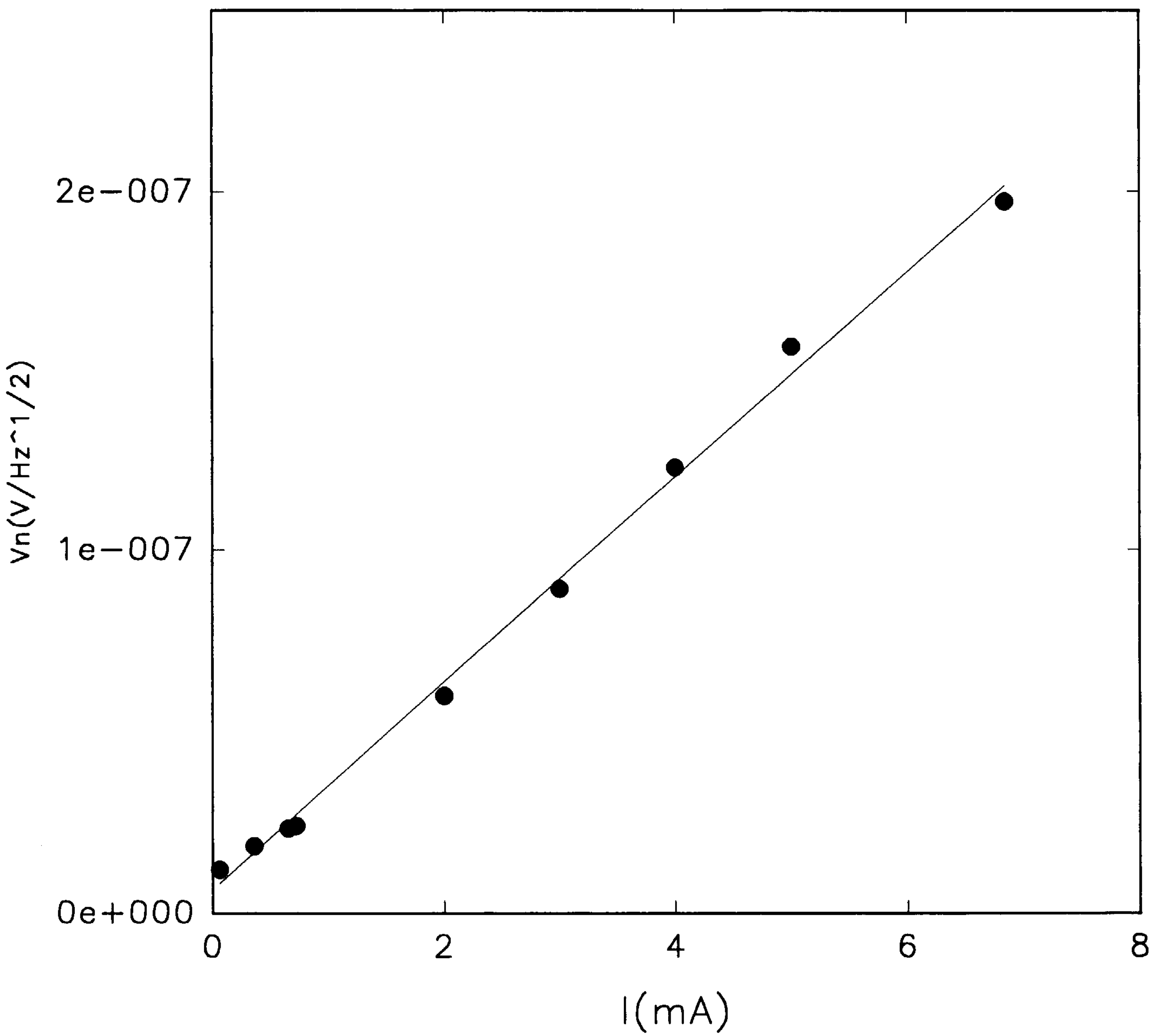
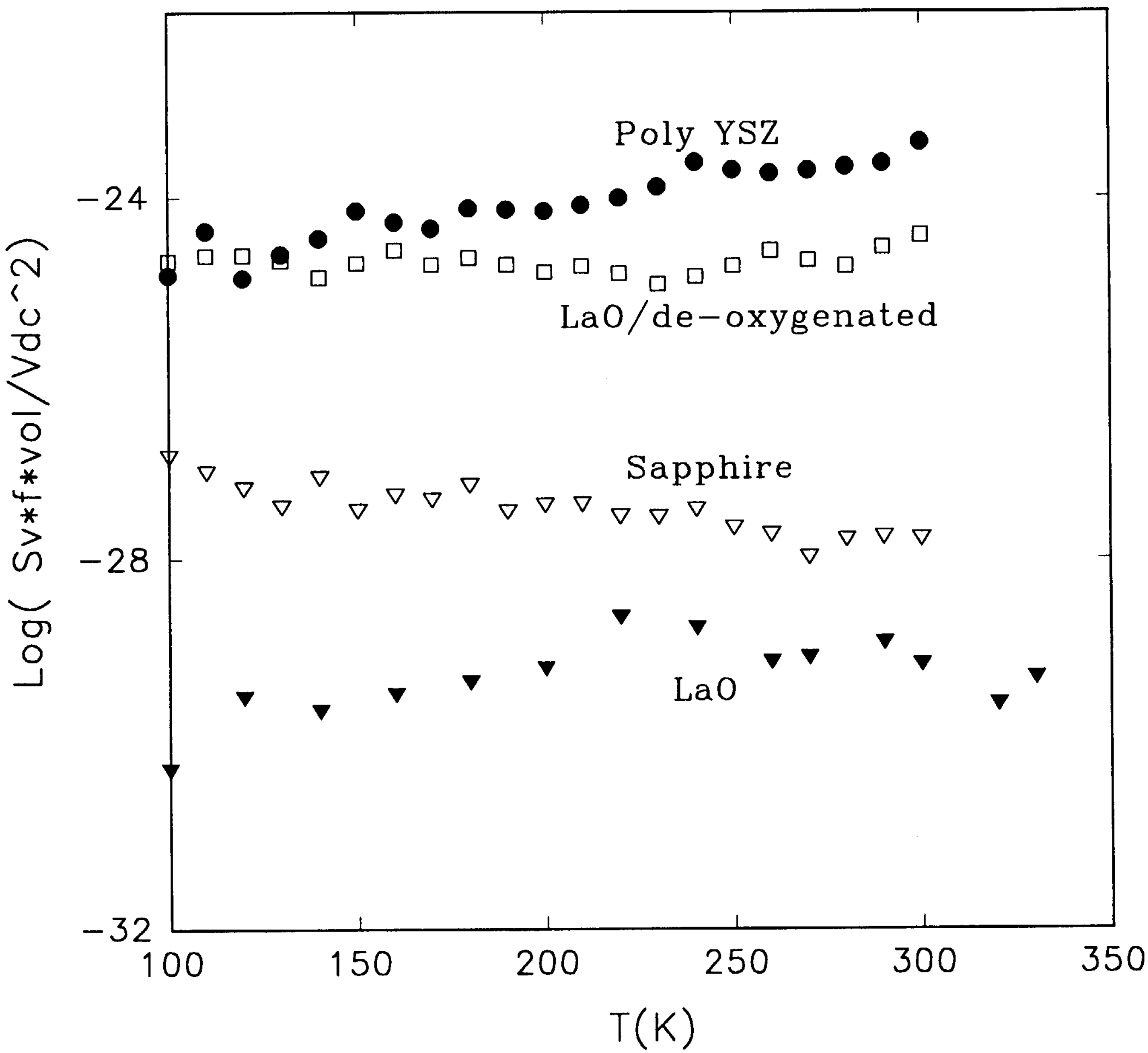


Fig. 3 Temperature Dependence of the Normalized Noise Spectral Density



Abstract Submitted
for the 1995 March Meeting of the
American Physical Society
20-24 March, 1995

Suggested Session Title:
Superconducting materials - Films.

March Sorting
Category: *30(a)*

DOPANT INCORPORATION IN EPITAXIAL THIN FILMS OF $YBa_2Cu_{3-x}M_xO_{7-\delta}$ by pulsed laser deposition. D.D. Choughule,* M. Rajeswari,+ S.B.Ogale,* L. Senapati**, R.P. Sharma, I. Takeuchi, S. Lakeou+ and T. Venkatesan, Department of Physics, University of Maryland, College Park MD 20742, * Department of Physics, University of Poona, Pune, India, +Department of Engineering and Technology, University of District of Columbia, Washington DC -20008, **Nuclear Science Center, New Delhi, India.

We have studied the systematics of the dopant incorporation during the pulsed laser deposition of epitaxial thin films of $YBa_2Cu_{3-x}M_xO_{7-\delta}$ where M represents Cu(1) site dopants (eg. Co, Fe, Ga) as well as Cu(2) site dopants (eg. Ni, Zn, Mn).. We find that the complete incorporation of dopants in several cases is not achieved under deposition conditions which are optimal for the preparation of high quality $YBa_2Cu_{3-x}O_{7-\delta}$ films. Further, the sensisitvity to deposition conditions is dopant- specific. We will discuss the effect of the deposition parameters on the dopant incorporation as revealed by RBS, X-ray, AFM and electrical transport measurements of films prepared under different conditions.

Partially supported by NASA grant G-5 2348 at Univ. of DC.

Prefer Standard Session

S. B. Ogale,
Department of Physics,
University of Poona,
Pune,
India.

Membership # m60013732

Abstract Submitted
for the 1995 March Meeting of the
American Physical Society
20-24 March, 1995

Suggested Session Title:
Electrical and magneto transport in superconducting thin films.

March Sorting
Category: *32(C)*

ELECTRICAL AND MAGNETO-TRANSPORT IN THE NORMAL STATE AND SUPERCONDUCTING STATE OF EPITAXIAL THIN FILMS OF $YBa_2Cu_{3-x}M_xO_{7-\delta}$.

M. Rajeswari,* D.D. Choughule,+ S.B.Ogale,+ P. Warburton, E.A.Wood, S. Lakeou,* and T. Venkatesan, Department of Physics, University of Maryland, College Park, MD 20742,
+ Department of Physics, University of Poona, Pune, India,
* Department of Engineering and Technology, University of District of Columbia, Washington DC -20008.

We will present our studies of the normal state and superconducting transport properties of epitaxial thin films of $YBa_2Cu_{3-x}M_xO_{7-\delta}$ where M represents Cu(1) site dopants (eg. Co, Fe, Ga) as well as Cu(2) site dopants (eg. Ni, Zn, Mn). Previous studies , based largely on bulk samples have shown that doping the Cu(2) sites results in enhanced Tc suppression while Cu(1) site doping is characterized by broadening of the transition. We will discuss electrical resistivity, Hall coefficients, critical current densities and electrical noise characteristics in the context of examining the effects of dopants on the normal state transport, suppression of superconducting transition temperatures as well as possible effects on interlayer coupling in the superconducting state.
Partially supported by NASA grant G-5 2348 at Univ. of DC.

Prefer Standard Session

M. Rajeswari
Department of Engineering and Technology,
University of the District of Columbia,
Washington DC -20008.

APS membership # M60012136

UNIVERSITY OF THE DISTRICT OF COLUMBIA

COLLEGE OF PROFESSIONAL STUDIES

Presents the

FALL 1994

LABORATORY FELLOWS

SEMINAR

Wednesday, December 14, 1994
10:00 a.m. to 12:00 Noon
Building 52 - Faculty Lounge

Tilden J. LeMelle, President
Julius F. Nimmons, Jr., Provost/VPAA
Philip L. Brach, Dean

Presentations

EVALUATION OF THE CRITICAL CURRENT J_c IN YBCO SUPER CONDUCTORS

Labaratory Fellow - Andryas Kidane

Mentor - Dr. Samuel Lakeou

FINANCIAL MANAGEMENT OF WATER AND SEWER IN BALTIMORE

Laboratory Fellow - Teresina Kiragu

Mentor - Dr. Yearn Choi

RE: APPLICATION OF *MAPLE* SOFTWARE TO MAGNETOSTATIC PROBLEMS

Laboratory Fellow - Medoune Seye

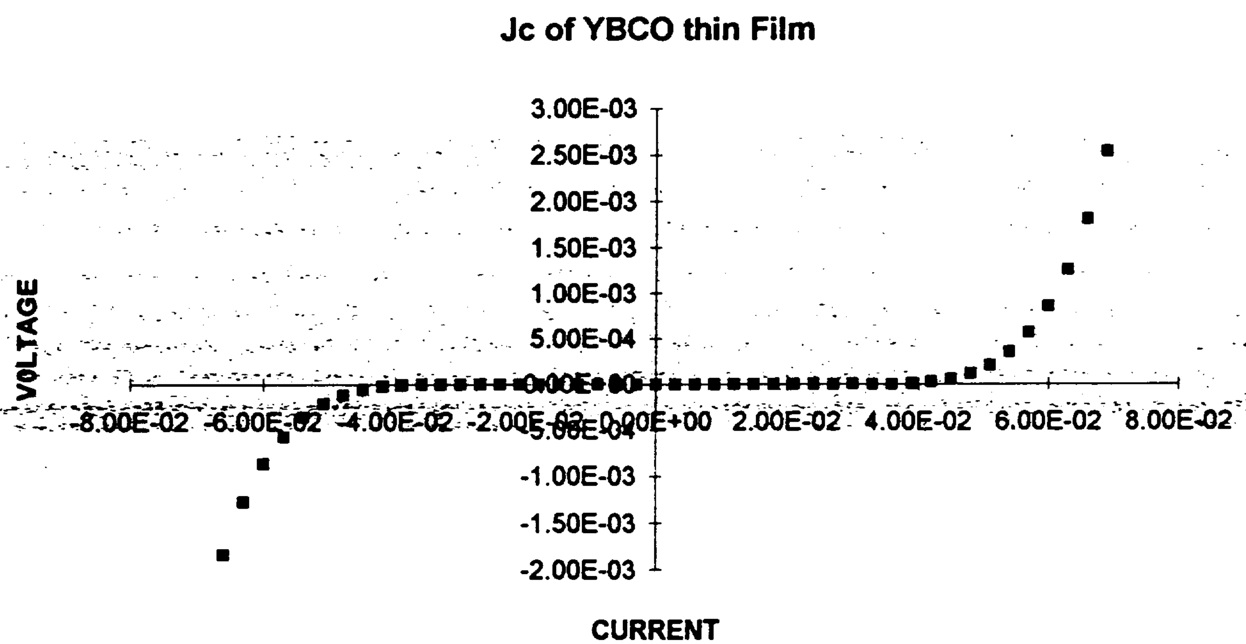
Mentor - Dr. Bing Liu

CONDUCTING A SEARCH THROUGH UDC AND ITS CONSORTIUM LIBRARIES

Laboratory Fellow - John Blunt

Mentor - Dr. Carlyle Hughes

Sample Jc Measurement Results from the work of the Lab Fellow



Temperature(K)	Critical Current (mA)	Critical Current density(A/m^2)
90	1	1.33×10^8
89	10	1.33×10^9
85	18	2.39×10^9
82	29	3.86×10^9
80	39	5.19×10^9
79	60	7.98×10^9
77	72	9.58×10^9
76	75	9.98×10^9